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The title of the invention has been amended (Guidelines for Examination in the EPO, A-III, 7.3).

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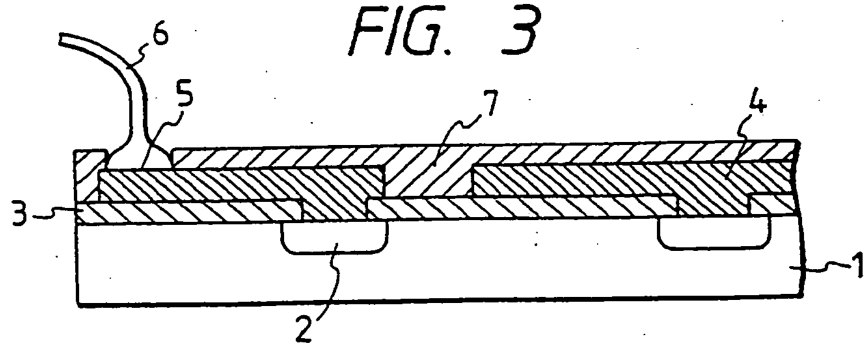
(54) Semiconductor device having a metallization film layer.

(57) A metallization film layer (4) disposed on a semiconductor chip (1) is made of Cu alloy which contains a metal element less noble than Cu and whose balance consists of Cu and unavoidable impurities. The metal element less noble than Cu is at least one kind of members selected from the group consisting of Al, Be, Cr, Fe, Mg, Ni, Si, Sn and Zn. Cu alloy as the metallization film layer (4) improves corrosion resistance by adding a trace amount of a metal element less noble than Cu within such a range where electric conductivity is not much reduced to Cu without lowering high electric conductivity, high heat resistance and high electro-migration resistance of Cu.

FIG. 3



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consists of Cu and unavoidable impurities as the material of a metallization film layer inside a semiconductor chip.

In other words, the present invention is characterized in that Cu alloy which improves corrosion resistance by adding a trace amount of a metal element less noble than Cu within such a range where electric conductivity is not much reduced to Cu without lowering high electric conductivity, high heat resistance and high electro-migration resistance of Cu, is used as the material of the metallization film layer.

A semiconductor device having high speed responsibility and high reliability can be provided by use of this metallization film layer material disposed on the semiconductor chip.

Next, how high speed responsibility and high reliability of the semiconductor device can be improved by use of Cu alloy containing a trace mount of a less noble metal element than Cu for the metallization film layer will be explained as follows.

The conducting delay time of a signal flowing through the metallization film layer inside the semiconductor chip is an important factor that determines high speed responsibility of the semiconductor device and its value is proportional to the electric resistance of the metallization film layer. Therefore, the conducting delay time is proportional to the length of the metallization film layer and its specific resistance and is inversely proportional to the metallization line of the metallization film layer.

To reduce the drop of the conducting delay time due to the reduction of the metallization line resulting from a higher integration density of the semiconductor chip, a metallization film layer material having a lower specific resistance must be used. Cu is an advantageous material because its specific resistance is 1.7 $\mu\Omega$cm which is by far lower than that of Al, i.e. 2.7 $\mu\Omega$cm. The melting point of Cu is by about 400 °C higher than that of Al and is more advantageous in the aspect of heat resistance, too.

Furthermore, as to the lamination defect energy which is a factor determining electro-migration resistance, Cu has 4.10^{-6} J/cm^2 (40 erg/cm^2) which is lower than 20.10^{-6} J/cm^2 (200 erg/cm^2) of Al. Though Cu has more excellent properties than Al as the metallization film layer material as described above, it involves the problem in corrosion resistance.

Cu is oxidized by several μm per hour in the atmosphere of 400 to 500 °C under the annealing condition after the formation of the metallization film layer, whereas Al is oxidized by only several tens of nm. In an aqueous solution environment, Cu and Al have almost equivalent corrosion resistance in a neutral solution but in an oxidizing solution such as nitro-hydrofluoric acid mixture, Cu is more likely to be corroded than Al.

Corrosion resistance of a metal depends on the protective property of the oxide film formed on the metal surface and whereas the oxide film consisting principally of Al_2O_3 which is formed on Al surface is extremely stable, CuO or Cu_2O formed on the surface of Cu has low protective property under the oxidizing environment.

Various corrosion-resistance Cu alloys have been developed to improve corrosion resistance of Cu, but since an alloy element or alloy elements are added in high concentration such as several percentages in the alloy or all these alloys, high electric conductivity of Cu drops remarkably and specific resistance of Cu becomes higher than that of Al.

It can be understood from the description given above, it is effective to add a trace amount of a corrosion resistance improving metal element in order to improve corrosion resistance of Cu without lowering its excellent properties.

Metal elements less noble than Cu are effective as the addition metal element. When Cu to which a less noble metal element is added is exposed to corrosive environment, Cu is not oxidized but the addition less noble metal element is selectively oxidized and its oxide film is formed on the surface of the metallization film layer. This oxide film serves as the protection thin film and restricts corrosion of Cu as a substrate or base layer.

Examples of the addition metal elements include Al, Be, Cr, Fe, Mg, Ni, Si, Sn and Zn; it is preferred to add at least one kind of metal element selected from the group described above.

When Al is added to Cu, Al is selectively oxidized under corrosive environment and Al_2O_3 formed on the surface acts to limit corrosion of Cu. The amount of addition for Al is preferably from 0.01 to 0.5 wt%. If the addition amount for Al is below this range, the effect of addition is not observed and if it is above this range, electric conductivity becomes lower than that of Al. When added to Cu, Al causes solid solution and exhibits reinforcement so that mechanical strength is increased and electro-migration resistance can be improved.

Each metal element of Be, Cr, Fe, Mg, Ni, Si, Sn and Zn is selectively oxidized when added to Cu, in the same way as Al, and the protection oxide film consisting principally of ach of BeO, Cr_2O_3, Fe_2O_3 + Fe_3O_4, MgO, Ni_2O_3 + Ni_3O_4, SiO_2, SnO_2 and ZnO is formed and improves corrosion r sistance. A suitable amount of addition for each metal element stated above is within such a range where electric conductivity is

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device by forming the metallization film layer having various compositions by sputtering by use of a 0.8 µm mask pattern for 4 mega DRAM on Si semiconductor chip.

High speed responsibility of the semiconductor chip was evaluated by measuring the time between the input and output of a signal pulse, that is, the conducting delay time.

A high temp rature wiring breakage ratio was measured as electro-migration resistance after the lapse of 500 hours at a high temperature current test causing a current of 10^6 A/cm^2 to flow through the wiring at 180 °C.

On the other hand, moisture resistance reliability of the semiconductor chip was evaluated by a PCT (pressure cooker test) left-standing wiring breakage ratio after the lapse of 250 hours by a PCT (pressure cooker test) test where each sample was left standing at 120 °C and 95% RH (relative humidity).

Table 1

	No.	circuit wiring composition	delay time (n sec)	high temperature power wiring breakage ratio (%)	PCT left-standing wiring breakage ratio (%)
Embodiments of Present Invention	1	Cu-0.1Al	31	<1	33
	2	Cu-0.1Be	31	<1	34
	3	Cu-0.1Cr	31	<1	33
	4	Cu-0.1Fe	31	<1	33
	5	Cu-0.1Mg	31	<1	34
	6	Cu-0.1Ni	30	<1	32
	7	Cu-0.1Si	31	<1	34
	8	Cu-0.1Sn	30	<1	32
	9	Cu-0.1Zn	29	<1	33
Comparative Examples	10	Cu	29	1	45
	11	Al	38	45	35
	12	Al-Si	39	42	33

As can be understood from Table 1, the semiconductor chips using the metallization film layer materials in accordance with various embodiments of the present invention have high speed responsibility and electro-migration resistance almost equivalent to those of the semiconductor chips using Cu metallization film layer material and more excellent than the semiconductor chip using Al type metallization film layer material.

On the other hand, moisture resistance reliability of the semiconductor chip is drastically improved in comparison with Comparative Example using Cu metallization film layer material, and is almost equivalent to that of the semiconductor chip using Al type metallization film layer material.

As described above, it is possible to provide a semiconductor device having high speed responsibility and high reliability by use of Cu alloy metallization film layer having the composition in accordance with various embodiments of the present invention.

When Cu alloy is used for the metallization film layer disposed on the semiconductor chip as described above, there can be obtained the semiconductor device having higher corrosion resistance, higher electro-migration resistance and higher speed responsibility than when Al type metallization film layer material is used.

Claims

1. A semiconductor device having a semiconductor chip (1), a diffusion layer (2) formed on said semiconductor chip (1), an insulator film layer (3) formed on said semiconductor chip (1), a metallization film layer (4) formed on said semiconductor chip (1), an electrod portion (5) formed on said metallization film layer (4), a protection film layer (7) formed on said metallization film layer (4), a wire (6) connected to

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FIG. 1

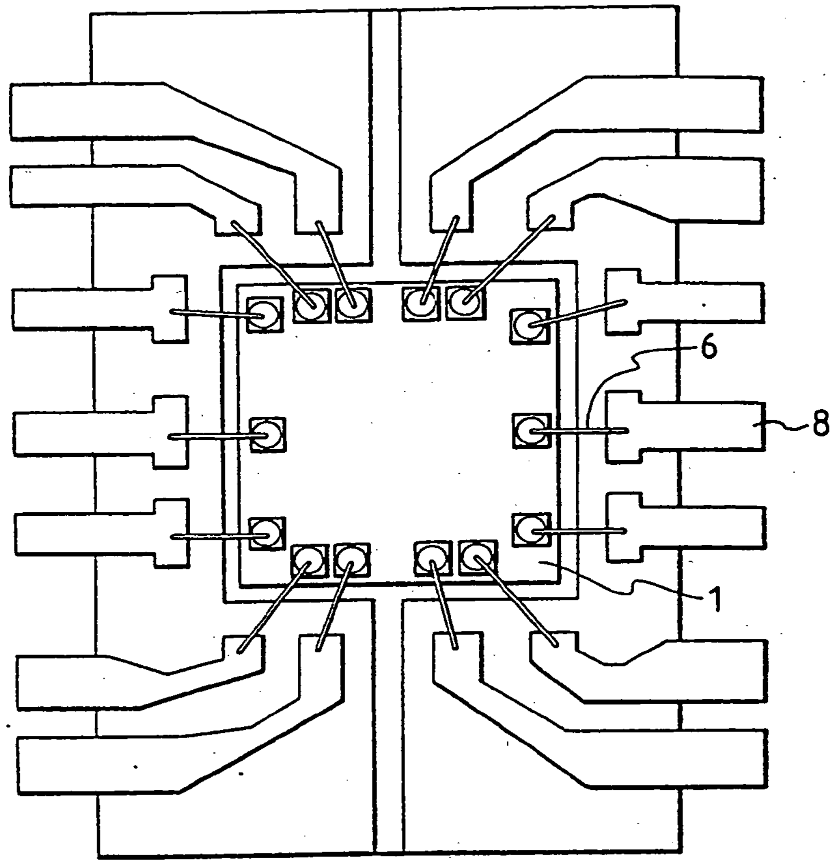


FIG. 2

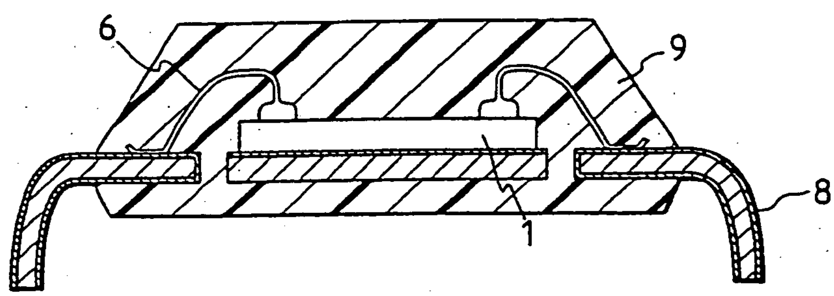
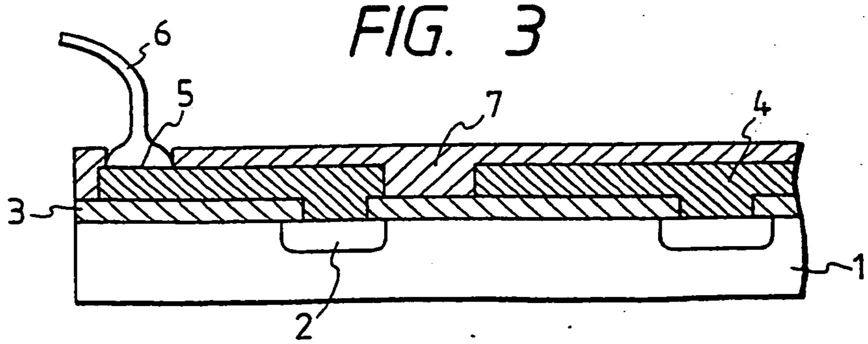


FIG. 3



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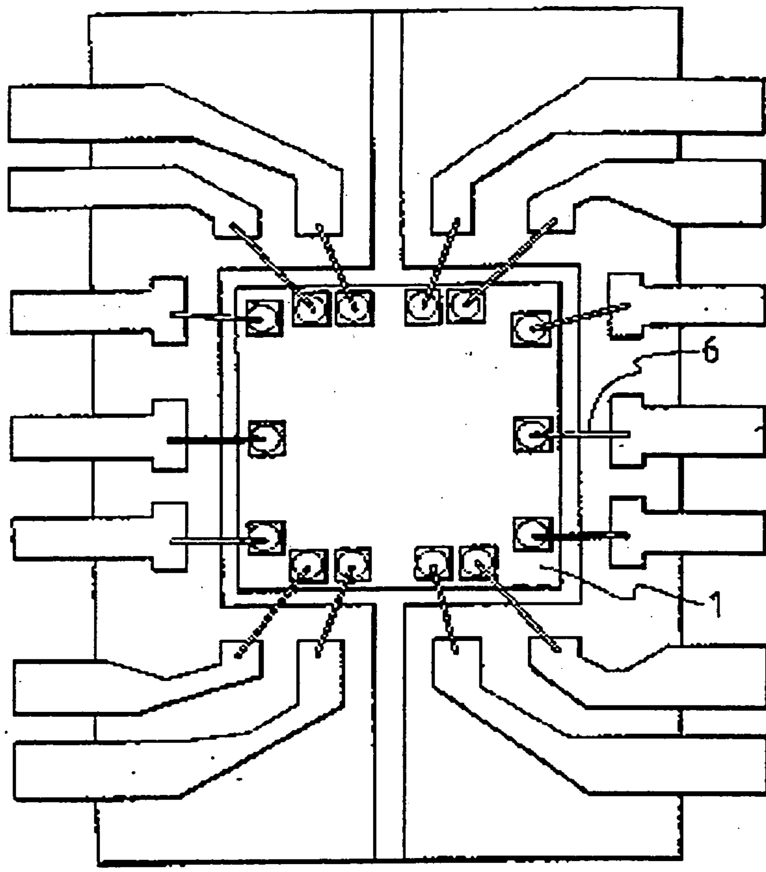
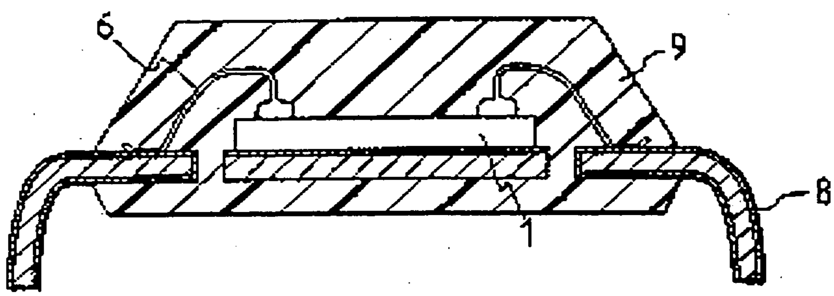


FIG. 2



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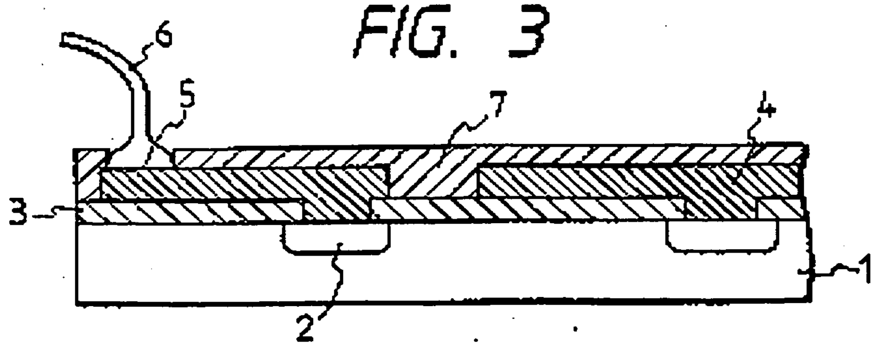

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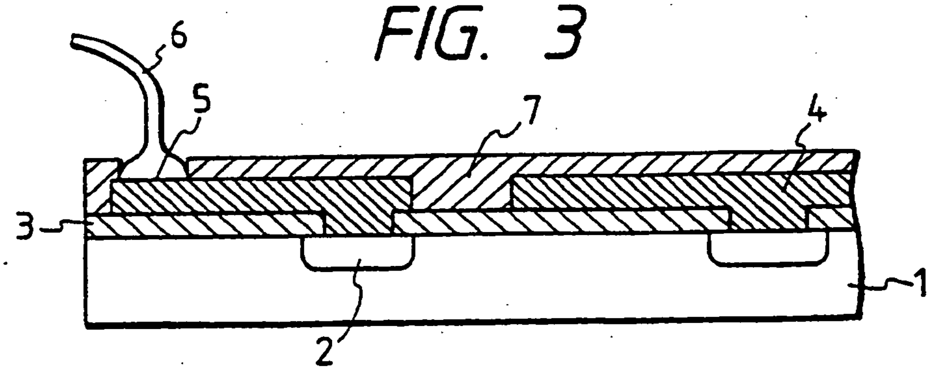

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European Patent Office

EUROPEAN SEARCH REPORT

Application Number

EP 89 10 5608

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl.4)
X	EP-A-0 260 906 (FUJITSU) * Claim 1; column 9, line 11 - column 10, line 14 *	1,5	H 01 L 23/48
A		2,6	

TECHNICAL FIELDS SEARCHED (Int. Cl.4)

H 01 L

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	01-03-1990	PHEASANT N.J.

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
Y : particularly relevant if combined with another document of the same category
A : technological background
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P : intermediate document

T : theory or principle underlying the invention
E : earlier patent document, but published on, or after the filing date
D : document cited in the application
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